which extracted the thermometers from their tube for the sake of the fur in which it has been found necessary to envelop them, and broke them all; other thermometers were, however, substituted, and the observations continued. It was found impossible to obtain the temperature of the soil at a greater depth than four feet, on account of the rocky nature of the ground.

A series of observations of terrestrial radiation was made by means of a thermometer placed on the surface of the snow, but the almost continual wind detracts much from the value of these readings.

I was told by the residents of the country that the year was an unusually dry one, and certainly the rainfall is remarkably small; they also said that the winter was particularly mild and free from storms, which, from all accounts, and from the journals kept at the fort, seem to be both frequent and severe; as it was, we only experienced one, in February.

Astronomical Observations.—My first determination of the longitude was made by means of lunar distances, and time was found by the method of equal altitudes, but after the observatory was finished both these points were determined by transits, and the first value of the longitude found to be more than a minute in error. The latitude was determined by transit observations in the prime vertical, and is probably within a few seconds of the truth. The longitude may be ten seconds in error. The time was generally correct to within three or four seconds.

A more solidly constructed transit instrument would have been desirable, as it was found that in the cold weather it required so much force to move the telescope of the transit theodolite on its axis that there was great risk of disturbing the adjustments of this instrument, composed as it is of so many parts.

Food, &c.—Our supply of provisions proved quite sufficient. I had brought enough flour to admit of my issuing the usual ration of ¾ lb. per diem, and tobacco 1 lb. per month to each man. We also had a supply of Chollet's preserved vegetables, and a reserve stock of bacon, besides tea and sugar. Of the latter we were somewhat short, owing to the loss sustained on the journey up. We usually had fresh meat throughout the winter; in the summer we were occasionally reduced to dried meat. During the journey there and back we chiefly lived on pemmican. The Rev. Père Roure, of the Roman Catholic Mission, most kindly furnished us with fresh vegetables and potatoes throughout the summer.

The conduct of the men under my command was everything that could be desired. They took great interest in the observations, and did their best to carry them out with accuracy and punctuality, and were always contented and cheerful, in spite of the inevitable discomforts of their winter quarters and the occasional hardships of the journey.

Return Journey.—We were running great risks of being overtaken by the winter, and therefore lost no time in our departure.

The last hourly observation was made at midnight on August 31, 1883, after which the instruments were dismounted and packed, their cases having been previously arranged in readiness outside the observatory. The remainder of the baggage was already in the boat, so that by 2.30 a.m. on September 1 we were *en route*, and reached Fort Chipewyan on September 17, and Portage la Loche on October 4, having experienced some delay in surmounting the rapids of the Clearwater, the hard frosts having frozen all the small tributary streams, thus considerably lowering the water in the river.

The boat awaiting us on the south side of the portage was frozen in, but fortunately the wind changed and the ice broke up before our arrival. Had it been otherwise, we must have waited until the rivers were thoroughly frozen and travelling with dog-trains possible. In that case we should have been compelled to abandon our instruments and baggage.

On the 21st we reached Carlton on the Saskatchewan, where we were detained a day, the man engaged to transport our baggage across the prairie having refused to proceed. Another man was engaged, and on October 31 we reached the railway at Qu'Appelle, arriving at Winnipeg the following day. We were fortunate in crossing the prairie with so little difficulty, as at the same time last year it was covered with three feet of snow.

At Winnipeg I remained a couple of days to adjust accounts with the Hudson's Bay Company, and on November 4 we started for Quebec, going by rail *via* Chicago. We reached Quebec on the 8th, and Liverpool on November 20.

In conclusion, I have to acknowledge the assistance received from the officers of the Hudson's Bay Company, who spared no trouble in carrying out my wishes, especially Chief Commissioner Grahame at Winnipeg, Chief Factors MacFarlane and Camsell in charge of the Athabasca and Mackenzie River Districts respectively, and Mr. King in charge at Fort Rae. To their hearty co-operation the success of the expedition is in great part due.

Results of Expedition.—The following is a list of the observations taken at Fort Rae, the result of our year's work there, which I have now the honour to lay before the Royal Society:—

Magnetic

Hourly—
Declination from September 3, 1882, to August 31, 1883.
Hor. Force ,, 4, ,, ,,
Vert. Force ,, 6, ,, ,,

Term Day—
In accordance with programme laid down by St. Petersburg Conference—from September 15, 1882, to August 15, 1883.

Occasional—
Absolute observations of Hor. Force Dip and Declination.

Meteorological

Hourly—
Barometer from Sept. 1, 1882, to Aug. 31, 1883.
Dry and Wet Bulb Therms. ,, ,, ,,
Anemometer ,, ,, ,,
Wind, Clouds, and Weather ,, ,, ,,
Aurora (when visible) ,, ,, ,,
Hair Hygrometer (when in working order).
Terrestrial Radn. (occasionally in clear weather).

Daily—
Max. and Min. Solar and Terrest. Radn. Therms.
Rain Gauge.

Earth Thermometers every two days.

THE EVIDENCE FOR EVOLUTION IN THE HISTORY OF THE EXTINCT MAMMALIA[1]

II.

COMING to the vertebræ as a part of the osseous system, I will mention the zygapophyses, or antero-posterior direct processes, of which the posterior looks down and the anterior looks up. They move on each other, and the vertebral column bends from side to side. In the lower forms of mammals they are always flat, and in the hoofed mammals of the Puerco period they are all flat. In the Wasatch period we get a single group in which the articulation, instead of being perfectly flat, comes to be rounded; in the later periods we get them very much rounded; and finally, in the latest forms, we get the double curve and the locking process in the vertebral column, which, as in the limb, secures the greatest strength with the greatest mobility. In the first stages of the growth of the spinal cord it is a notochord or a cylinder of cartilage or softer material. In later stages the bony deposit is made in its sheath until it is perfectly segmented.

Now all the Permian land animals, reptiles, and batrachians retain this notochord with the beginnings of osseous vertebræ in a greater or less degree of complexity. There are some in South Africa, I believe, in which the ossification has come clear through the notochord, but they are few. This characteristic of the Permian appears almost alone—perhaps absolutely alone as regards land animals. There is something to be said as to the condition of that column from a mechanical standpoint, and it is this: that the cord exists, its osseous elements disposed about it; and in the batrachians related to the salamanders and the frogs, these osseous elements are arranged under the sheath in the skin of the cord, and they are in the form of regular concave segments, very much like such segments as you will take from the skin of an orange—parts of spheres, and having greater or less dimensions according to the group or species. Now the point of divergence of these segments is on the side of the column. They are placed on the side of the column where the segments separate—the upper segments rising and the lower segments coming downward. To the upper segments are attached the arches and their articulations; and the lower segments are like

---

[1] A lecture by Prof. E. D. Cope of Philadelphia, given in general session before the American Association for Advancement of Science at Minneapolis, August 20, 1883. Stenographically reported for *Science*. Continued from p. 230.

the segments of a sphere. If you take a flexible cylinder and cover it with a more or less inflexible skin or sheath, and bend that cylinder sidewise, you of course will find that the fractures of that part of the surface will take place along the line of the shortest curve, which is on the side; and, as a matter of fact, you have breaks of very much the character of the segments of the Permian batrachia. It may not be so symmetrical as in the actual animal, for organic growth is symmetrical so far as not interfered with; for, when we have two forces, the one of growth and the other of change or alteration, and they contend, you will find in the organic being a quite symmetrical result. That is the universal rule. In the cylinder bending in this way, of course the shortest line of curve is right at the centre of the side of that cylinder, and the longest curve is of course at the summit and base, and the shortest curve will be the point of fracture. And that is exactly what I presume has happened in the case of the construction of the segments of the sheath of the vertebral column in the lateral motion of the animal swimming always on one side, and which at least has been the actual cause of the disposition of the osseous material in its form. I have gone beyond the state of the discussion in calling attention to one of the forces which have probably produced this kind of result. That is the state of the vertebral column of many of the vertebrata of the Permian period.

I go back to the mammalia, and call attention to the teeth. The ordinary tooth of the higher type of the mammalia, whether hoofed or not, with some exceptions, is complex with crests or cusps. In cutting the complex grinding surfaces we find they have been derived by the unfolding extensions of four original cusps or tubercles. They have been flattened, have been rendered oblique, have run together, have folded up, have become spiked, have descended deeply or have lifted themselves, so that we have teeth of all sorts and kinds, oftentimes very elegant, and sometimes very effective in mechanism. In many primary ungulates, the primitive condition of four conical tubercles is found. In passing to older periods we find the mammalia of the Puerco period, which never have more than three tubercles, with the exception of three or four species. In the succeeding periods, however, they get the fourth tubercle on the posterior side. Finally, you get a complicated series of grinding or cutting apparatus, as the case may be.

Last, but not least, we take the series of the brain. No doubt the generalisation is true, that the primitive forms of mammalia had small brains with smooth hemispheres; later ones had larger brains with complex hemispheres. In general, the carnivora have retained a more simple form of brain, while herbivorous animals have retained a most complicated type of brain. The lowest forms of mammalia display the additional peculiarity of having the middle brain exposed, and the hemispheres or large lobes of the brain, which are supposed to be the seat of the mental phenomena, are so reduced in size at the back end that you see the middle brain distinctly, though it is smaller than in reptiles and fishes. It is beyond the possibility of controversy that these series have existed, and that they have originated in simplicity, and have resulted in complication; and the further deduction must be drawn, that the process of succession has always been towards greater effectiveness of mechanical work. There are cases of degradation, as in the growing deficiency in dentition in man. There is no doubt that a large number of people are now losing their wisdom-teeth in both jaws.

We are now brought to the question of the relations which mind bears to these principles. The question as to the nature of mind is not so complex as it might seem. There is a great deal of it, to be sure; but on examination it resolves itself into a few ultimate forms. An analysis reduces it to a few principal types or departments—the departments of intelligence and of emotions (with their modified smaller forms, likes and dislikes), and the will, if such there be. Those three groups, proposed by Kant, are well known, and adopted by many metaphysicians; and they stand the scrutiny of modern science perfectly well in both men and the lower animals. But the question of the material of the mind, the original raw stuff out of which mind was made, is one which is claiming attention now from biologists, as it always has done from physiologists proper and physicians. This is sensibility, mere simple sensibility, unmodified sensibility, or consciousness. Sensibility, in connection with memory, is sufficient for the accomplishment of wonderful results. It is only necessary to impress the sensibility with the stimuli which this world affords, whether from the outside or the inside, to have the record made, and to have the record kept. Among wonderful things this is perhaps the most wonderful: that any given form of matter should be able to retain a record of events, a record which is made during a state of sensibility for the most part, a greater or less degree of sensibility, which is retained in a state of insensibility, and is finally returned to the sensibility by some curious process of adhesion, and the results of impresses which are found on the material tissue concerned.

And these simple elements of mind are found in animals. No zoologist who has perception or honesty, nor any farmer or breeder, nor any person who has charge of animals in any way, can deny sensibility to all the lower animals at times. The great stumbling-block in the way of the thinker in all this field is the great evanescence of this sensibility: the great ease with which we dissipate it, the readiness with which we can deprive a fellow-being of his sense, is a stumbling-block in more ways than one. While it is a question of the greatest difficulty, nevertheless, like other departments of nature, doubtless it will ultimately be explained by the researches of physiologists. I only need to call attention to the fact as an important factor in evolution.

Of course, if these structures are suggested, affecting the mechanical apparatus, the question arises whether they were made ready to hand, whether the animal, as soon as he got it, undertook to use it, and whether he undertook to use the organism under the dire stimuli of necessity, or amended through ages these modifications in his own structure. We are told by some of our friends that law implies a Lawgiver, that evolution implies an Evolver; the only question is, Where is the Lawgiver? where is the Evolver? where are they located? I may say, it is distinctly proven in some directions, that the constant applications of force or motion in the form of strains, in the form of impacts and blows, upon any given part of the animal organism, do not fail to produce results in change of structure. I believe the changes in the ungulates to which I have called your attention are the result of strains and impacts, precisely as I have shown you the manner of the fracture of the vertebral column of the primitive vertebrates of the Permian period. This would require long discussion to render clear; nevertheless I venture to make the assertion that this series of structures is the result of definite and distinct organic forces, directed to special ends. We have yet to get at the conflicting forces which have produced the results we see. Mechanical evolution will give us a good deal to do for some time to come. Of course, if motion has had an effect in modifying structure, it behoves us to investigate those forces which give origin to motion in animals. First in order come the sensibilities of the animal, which we have traced to simple consciousness; stimuli, upon notice of which he immediately begins to move. The primary stimulus of all kinds of motion is necessarily touch. If a stone falls upon the tail of some animal which has a tail, he immediately gets out of that vicinity. If a jellyfish with a stinging apparatus runs across an eel which has no scales, the eel promptly removes. External applications of unpleasant bodies will always cause an animal to change his location. Then he is constantly assaulted by the dire enemy of beasts, hunger, which is an instinct which is evidently universal, to judge from the actions of animals. This seems to have fashioned, in large part, all forms of life, from the least to the greatest, from the most unorganised to the most complex. Each exercised itself for the purpose of filling its stomach with protoplasm. Then come the stimuli, which should be included under the class of touch, changes of temperature. No animals like to be cold or too hot; and when the temperature is disagreeable the tendency is to go away from that locality. Among primary instincts must be included that of reproduction. After that comes the sensation of resistance, or, carried to a high degree, of anger: when an animal's interests are interfered with, its movements resisted, it prompts to the most energetic displays. So you see it is a matter of necessity that mental phenomena lie at the back of evolution, always provided that the connecting link of the argument—that motion has ever affected structure—be true. That is a point which of course admits of much discussion. I have placed myself on the affirmative side of that question; and, if I live long enough, I expect to see it absolutely demonstrated.

Of course the development of mind becomes possible under such circumstances. It is not like a man lifting himself up by his boots, which it would be if he had no such thing as memory. But with that memory which accumulates, which formulates first habits, and then structures, especially in the soft, delicate nervous tissue, the development of the mind as well as the machinery of the mind becomes perfectly possible. We develop our intellect through the accumulation of exact facts, through the collation of pure facts, no matter whether it be a humble kind of a truth—as the knowledge of the changes of the seasons, which induces some animals to lay up the winter's store—whether it be knowledge of the fact that the sting of the bee is very unpleasant, or knowledge of the fact (of which the ox, no doubt, is thoroughly aware) that the teeth of the wolf are not pleasant to come in contact with, or whether it be the complex knowledge of man. When the cerebral matter has become larger and more complex, it receives and retains a much greater number of impressions, and the animal becomes a more highly educated being.

As regards the department of emotions or passions, it is also much stimulated by the environment. Animals which live in a state of constant strife naturally have their antagonistic passions much developed, while amiable, sympathetic sentiments are better and more largely produced by peace-loving animals. Thus it is that the various departments of the mind have the beautiful results which we now find in the human species.

There are some departments of the mind which some of our friends decline to admit having had such an origin. The moral faculty, for instance, is excepted by many from this series. But the reasons why they object to its production in this way are, to my mind, not valid. The development of the moral faculty, which is essentially the sense of justice, appears to them not to fall within the scope of a theory of descent or of evolution. It consists of two parts. First is the sentiment of benevolence, or of sympathy with mankind, which gives us the desire to treat them as they should be treated. It is not sufficient for justice that it is unmixed mercy, or benevolence, which is sometimes very injurious, and very often misplaced. It requires, in the second place, the criticism of the judgment, of the mature intellect, of the rational faculty, to enable the possessor to dispose of his sentiments in the proper manner. The combination of rational discrimination and true judgment with benevolence constitutes the sense of justice, which has been derived, no doubt, as a summary of the development of those two departments of the mind, the emotions and the intellect.

It is said that a sense of justice could not be derived from the sense of no justice; that it could not have been derived from the state of things which we find in the animals, because no animal is known to exhibit real justice: and that objection is valid as far as it goes. I suspect that no animal has been observed to show a true sense of justice. That they show sympathy and kindness there is no question; but when it comes to real justice they do not display it. But do all men display justice? Do all men *understand* justice? I am very sure not. There are a good many men in civilised communities, and there are many tribes, who do not know what justice is. It does not exist as a part of every mental constitution. I never lived among the Bushmen, and do not know exactly what their mental constitution is; but in a general way the justice of savages is restricted to the very smallest possible circle—that of their tribe or of their own family. There is a class of people who do not understand justice. I do not refer to people who know what right is, and do not do it; but to the primitive state of moral character, in which, as in children, a sense of justice is unknown. I call attention to the fact because some of our friends have been very much afraid that the demonstration of the law of evolution, physical and metaphysical, would result in danger to society. I suspect not. The mode in which I understand this question appears to me to be beneficial to society, rather than injurious; and I therefore take the liberty of appending this part of the subject to its more material aspect.

To refer to another topic, and that is to the origin of life, the physical basis of life. The word "life" is so complex that it is necessary to define it, and so to define it away that really the word "life" does not retain its usual definition. Many phenomena of life are chemical, physical, mechanical. We have to remove all these from consideration, because they come within the ordinary laws of mechanical forces; but we have a few things left which are of a different character. One is the law of growth, which is displayed in the processes of embryonic succession; secondly, the wonderful phenomena of sensibility. Those two things we have not yet reduced to any identity with the ordinary laws of force. In the phenomena of embryology the phenomena of evolution are repeated, only concentrated in the early stages through which animals have to pass. So whatever explains the general phenomena of evolution explains the phenomena of embryology.

What is the nature of physical sensibility? In this planet it is found residing only in one form of matter which has a slightly varied chemical constitution, namely, protoplasm; so called from a physical standpoint. Now this world, as you all know, has passed through many changes of temperature. Its early periods, it is probable, were so very hot that protoplasm had a very poor chance. The earth has passed through a great many changes of temperature, many of which would not permit the existence of protoplasm. Again, can we assume for a moment that this little speck in the great universe is the only seat of life? I suppose scarcely any scientific man will venture to do so. If, therefore, life exists in other parts of this great universe, does it necessarily occupy bodies of protoplasm in those different, remote spheres? It would be a great assumption. It is altogether improbable. The certainty is that in those planets which are in proximity to the sun's heat there could be no protoplasm. Protoplasm in the remote planets would be a hard mineral, and near the sun it would be dissipated into its component gases. So that, if life be found in other parts of this universe, it must reside in some different kind of material. It is extremely probable that the physical conditions that reside in protoplasm might be found in other kinds of matter. It is in its chemical inertness and in its physical constitution that its adaptation to life resides; and the physical constitution necessary for the sustentation of life may be well supposed to exist in matter in other parts of the universe. I only say the door is open and not closed: any one who asserts that life cannot exist in any other material basis than protoplasm is assuming more than the world of science will permit him to assume. And that it is confined to this single planet, and not in the great systems of the universe,—that assumption will not for a moment be allowed. Therefore the subject is one which allows us a free field for future investigation: it is by no means closed in the most important laws which it presents to the rational thinker. I hope, therefore, if the evidence in favour of this hypothesis of the creation of living forms be regarded as true, that no one will find in it any ground for any very serious modification of existing ideas on the great questions of right and wrong, which have long since been known by men as a result of ordinary experience, and without any scientific demonstration whatsoever.

THE REMARKABLE SUNSETS

We have received the following further communications on this subject:—

Referring to Mr. Meldola's letter in your last number (p. 224), I beg leave to state that I likewise observed an astonishing atmospheric luminosity, outside of this town, at 2–3 a.m. in the moonless and foggy night of January 1–2. It is reported that in these days the "Dämerungserscheinungen" have again been very striking at many places in Germany. Here the state of the atmosphere has of late been unfavourable for observing these phenomena; their most brilliant display, a "red glow" of extraordinary extent and intensity, I witnessed on the morning of December 1, beginning about two hours before sunrise.

The view that these luminosities are caused by volcanic dust acting as nuclei for the condensation of vapour in the higher strata of the atmosphere will have suggested to many of your readers the probability of so-called cosmical dust being often derivable from similar terrestrial sources. To me it has, moreover, recalled an hypothesis on the origin of meteorites, put forth some twenty years ago in an elaborate treatise by Mr. P. A. Kesselmeyer of Frankfort-on-the-Maine ("Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft," vol. iii.). Mr. Kesselmeyer contends for the derivation of meteorites from condensation of metallic and other vapours issued from volcanoes; he distinctly supposes those of Eastern Asia as chief sources, and, among other ingenious reasons for these views, he particularly insists on remarkable statistics of geographical and seasonal distribution of stone-falls (Nature, vol. xvi. p. 558).

I am well aware of the momentous difficulties of this hypothesis, which fails to explain why such masses of vapour (or dust), after travelling for enormous distances, become condensed into solid bodies. On the other hand, there appears to me not to be such a contradiction to astronomical theories as might seem at first sight; the view in question would merely involve the assumption that there are fireballs and fireballs: those which